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1. GENERAL BACKGROUND INFORMATION

ACRONYMS AND ABBREVIATIONS USED IN THIS BULLETIN

ACTS	- Automated Computer Time Service		
BIPM	- Bureau International des Poids et Mesures		
Cs	- Cesium standard		
GPS	- Global Positioning System		
IERS	- International Earth Rotation Service		
LORAN	- Long Range Navigation		
MC	- Master Clock		
MJD	- Modified Julian Date		
NVLAP	- National Voluntary Laboratory Accreditation Program		
NIST	- National Institute of Standards and Technology		
NOAA	- National Oceanic and Atmospheric Administration	ns	- nanosecond
SI	- International System of Units	μs	- microsecond
TA	- Atomic Time	ms	- millisecond
TAI	- International Atomic Time	s	- second
USNO	- United States Naval Observatory	min	- minute
UTC	- Coordinated Universal Time		

2. TIME SCALE INFORMATION

The values listed below are based on data from the IERS, the USNO, and NIST. The UTC(USNO,MC) - UTC(NIST) values are averaged measurements from all available common-view GPS satellites (see bibliography on page 5). **UTC - UTC(NIST) data are on page 3.**

0000 HOURS COORDINATED UNIVERSAL TIME			
DEC 2003	MJD	UT1-UTC(NIST) (±5 ms)	UTC(USNO,MC) - UTC(NIST) (±20 ns)
4	52977	-383 ms	-13 ns
11	52984	-383 ms	-12 ns
18	52991	-383 ms	-17 ns
25	52998	-383 ms	-16 ns

The master clock pulses used by the WWV, WWVH, and WWVB time-code transmissions are referenced to the UTC(NIST) time scale. Occasionally, 1 s is added to the UTC time scale. This second is called a leap second. Its purpose is to keep the UTC time scale within ±0.9 s of the UT1 astronomical time scale, which changes slightly due to variations in the Earth's rotation.

NOTE: There was no leap second inserted at the end of December 2003.

Positive leap seconds, beginning at 23 h 59 min 60 s UTC and ending at 0 h 0 min 0 s UTC, were inserted in the UTC timescale on 30 June 1972, 1981-1983, 1985, 1992, 1993, 1994, and 1997, and on 31 December 1972-1979, 1987, 1989, 1990, 1995, and 1998.

The use of leap seconds ensures that UT1 - UTC will always be held within ±0.9 s. The current value of UT1 - UTC is called the DUT1 correction. DUT1 corrections are broadcast by WWV, WWVH, WWVB, and ACTS and are printed below. These corrections may be added to received UTC time signals in order to obtain UT1.

DUT1 = UT1 - UTC =

+0.1 s beginning 0000 UTC 19 October 2000
+0.0 s beginning 0000 UTC 01 March 2001
-0.1 s beginning 0000 UTC 04 October 2001
-0.2 s beginning 0000 UTC 14 February 2002
-0.3 s beginning 0000 UTC 24 October 2002
-0.4 s beginning 0000 UTC 03 April 2003

The difference between UTC(NIST) from UTC has been within ± 100 ns since July 6, 1994. The table below shows values of UTC - UTC(NIST) as supplied by the BIPM in their Circular T publication for the most recent 310-day period in which data are available. Data are given at ten-day intervals. Five-day interval data are available in Circular T.

0000 Hours Coordinated Universal Time

DATE	MJD	UTC-UTC(NIST) ns
Nov. 26, 2003	52969	-1.1
Nov. 16, 2003	52959	2.0
Nov. 6, 2003	52949	2.1
Oct. 27, 2003	52939	1.8
Oct. 17, 2003	52929	1.2
Oct. 7, 2003	52919	3.9
Sep. 27, 2003	52909	7.9
Sep. 17, 2003	52899	7.5
Sep. 7, 2003	52889	7.6
Aug. 28, 2003	52879	7.7
Aug. 18, 2003	52869	8.0
Aug. 8, 2003	52859	10.2
Jul. 29, 2003	52849	10.7
Jul. 19, 2003	52839	12.7
Jul. 9, 2003	52829	12.6
Jun. 29, 2003	52819	9.2
Jun. 19, 2003	52809	7.5
Jun. 9, 2003	52799	3.8
May 30, 2003	52789	0.6
May 20, 2003	52779	4.0
May 10, 2003	52769	10.4
Apr. 30, 2003	52759	8.9
Apr. 20, 2003	52749	10.7
Apr. 10, 2003	52739	10.9
Mar. 31, 2003	52729	11
Mar. 21, 2003	52719	12
Mar. 11, 2003	52709	11
Mar. 1, 2003	52699	7
Feb. 19, 2003	52689	8
Feb. 9, 2003	52679	7

3. PHASE DEVIATIONS FOR WWVB AND LORAN-C

- WWVB - The values shown for WWVB are the time differences between the time markers of the UTC(NIST) time scale and the first positive-going zero voltage crossover measured at the transmitting antenna. The uncertainty of the individual measurements is $\pm 0.5 \mu\text{s}$. The values listed are for 1300 UTC.
- LORAN-C - The values shown for Loran-C represent the daily accumulated phase shift (in ns). The phase shift is measured by comparing the output of a Loran receiver to the UTC(NIST) time scale for a period of 24 h. If data were not recorded on a particular day, the symbol (-) is printed. The stations monitored are Baudette, ND (8970-Y) and Fallon, NV (9940). The monitoring is done from the NIST laboratories in Boulder, Colorado.

Note: The values shown for Loran-C are in nanoseconds.

		<u>UTC(NIST)-WWVB (60 kHz)</u>		<u>UTC(NIST) - LORAN PHASE (ns)</u>	
		ANTENNA PHASE	LORAN-C (BAUDETTE)	LORAN-C (FALLON)	
DATE	MJD	(μs)	(8970)	(9940)	
12/01/03	52974	5.61	-16	-242	
12/02/03	52975	5.59	+27	-8	
12/03/03	52976	5.60	+53	+37	
12/04/03	52977	5.57	+50	+574	
12/05/03	52978	5.58	+5	-376	
12/06/03	52979	5.56	-155	+23	
12/07/03	52980	5.54	+189	+453	
12/08/03	52981	5.53	-132	+183	
12/09/03	52982	5.53	-68	-309	
12/10/03	52983	5.54	-25	+489	
12/11/03	52984	5.53	+228	-496	
12/12/03	52985	5.52	+63	+188	
12/13/03	52986	5.50	-21	-314	
12/14/03	52987	5.50	+28	+150	
12/15/03	52988	5.50	-47	+371	
12/16/03	52989	5.50	-95	-360	
12/17/03	52990	5.50	+183	-13	
12/18/03	52991	5.50	+118	-95	
12/19/03	52992	5.50	-26	+296	
12/20/03	52993	5.50	+43	-60	
12/21/03	52994	5.50	-210	+38	
12/22/03	52995	5.50	+6	-365	
12/23/03	52996	5.51	-8	-218	
12/24/03	52997	5.52	+180	+194	
12/25/03	52998	5.53	+14	-423	
12/26/03	52999	5.54	-3	-172	
12/27/03	53000	5.54	-9	+133	
12/28/03	53001	5.54	-16	-110	
12/29/03	53002	5.54	+20	-38	
12/30/03	53003	5.55	-63	-121	
12/31/03	53004	5.55	+54	+255	

4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB PHASE PERTURBATIONS

OUTAGES OF 5 MINUTES OR MORE						PHASE PERTURBATIONS 2 ms			
Station	DEC 2003	MJD	Began UTC	Ended UTC	Freq.	DEC 2003	MJD	Began UTC	End UTC
WWVB	12-27-03	53000	0507	0508	60 kHz				
WWV	12-01-03	52974	2126	2131	10 MHz				
WWV	12-01-03	52974	2126	2131	5 MHz				

WWVB operated at reduced power during the time periods listed in the table below. The station normally outputs 50 kW.

Date	MJD	Began (UTC)	Ended (UTC)	Power Level
12-02-03	52975	1500	2345	29 kW
12-01-03	52974	1500	2345	29 kW

5. NOTES ON NIST TIME SCALES AND PRIMARY STANDARDS

Primary frequency standards developed and operated by NIST are used to provide accuracy (rate) input to the BIPM. NIST-7 was the U.S. primary standard from 1994 to 1999, when it was replaced by NIST-F1, a cold-atom cesium fountain frequency standard. The uncertainty of NIST-F1 is currently about 1 part in 10^{15} .

The AT1 scale is run in real-time by use of data from an ensemble of cesium standards and hydrogen masers. It is a free-running scale whose frequency is maintained as nearly constant as possible by choosing the optimum weight for each clock that contributes to the computation.

UTC(NIST) is generated as an offset from our real-time scale AT1. It is steered in frequency towards UTC by use of data published by the BIPM in its Circular T. Changes in the steering frequency will be made, if necessary, at 0000 UTC on the first day of the month, and occasionally at mid-month. A change in frequency is limited to no more than ± 2 ns/day. The frequency of UTC(NIST) is kept as stable as possible at other times.

UTC is generated at the BIPM using a post-processed time-scale algorithm and is not available in real-time. The parameters that we use to generate UTC(NIST) in real-time are therefore based on an extrapolation of UTC from the most recent available data.

6. BIBLIOGRAPHY

Allan, D.W.; Hellwig, H.; and Glaze, D.J., "An accuracy algorithm for an atomic time scale," *Metrologia*, Vol.11, No.3, pp.133-138 (1975).

Allan, D.W.; Davis, D.D.; Weiss, M.A.; Clements, A.; Guinot, B.; Granveaud, M.; Dorenwendt, K.; Fischer, B.; Hetzel, P.; Aoki, S.; Fujimoto, M.; Charron, L.; and Ashby, N., "Accuracy of International Time and Frequency Comparisons Via Global Positioning System Satellites in Common-view," *IEEE Transactions on Instrumentation and Measurement*, Vol. IM-34, pp.118-125, 1985.

Jefferts, S.R.; Shirley, J.; Parker, T.E.; Heavner, T.P.; Meekhof, D.M.; Nelson, C.; Levi, F.; Costanza, G.; De Marchi, A.; Drullinger, R.; Hollberg, L.; Lee, W.D.; and Walls, F.L., "Accuracy evaluation of NIST-F1," *Metrologia*, Vol. 39, pp. 321-336, (2002).

Lewandowski, W. and Thomas, C.; "GPS Time transfer," *Proceedings of the IEEE*, Vol. 79, pp. 991-1000, 1991.

Shirley, J.H.; Lee, W.D.; Drullinger, R.E.; "Accuracy evaluation of the primary frequency standard NIST-7," *Metrologia*, Vol. 38, pp. 427-458, (2001).

Weiss, M.A.; Allan, D.W.; "An NBS Calibration Procedure for Providing Time and Frequency at a Remote Site by Weighting and Smoothing of GPS Common View Data," *IEEE Transactions on Instrumentation and Measurement*, Vol. IM-36, pp. 572-578, 1987.

Table 7.1 lists parameters that are used to define UTC(NIST) with respect to our real-time scale AT1. To find the value of UTC(NIST) - AT1 at any time T (expressed as a Modified Julian Day, including a fraction if needed), the appropriate equation to use is the one for which the desired T is greater than or equal to the entry in the T_0 column and less than the entry in the last column. The values of x_s , x , and y for that month are then used in the equation below to find the desired value. The parameters x and y represent the offset in time and in frequency, respectively, between UTC(NIST) and AT1; the parameter x_s is the number of leap seconds applied to both UTC(NIST) and UTC as specified by the IERS. Leap seconds are not applied to AT1.

Table 7.1 UTC(NIST) - AT1 = $x_s + x + y*(T - T_0)$					
Month	x_s (s)	x (ns)	y (ns/d)	T_0 (MJD)	Valid until 0000 on: (MJD)
Jan 03	-32	-258738.5	-39.5	53005	53036*
Dec 03	-32	-258343.5	-39.5	52995	53005
Dec 03	-32	-257516.1	-39.4	52974	52995†
Nov 03	-32	-256925.1	-39.4	52959	52974
Nov 03	-32	-256334.85	-39.35	52944	52959†
Oct 03	-32	-255783.95	-39.35	52930	52944
Oct 03	-32	-255112.45	-39.5	52913	52930†
Sep 03	-32	-253927.745	-39.5	52883	52913
Aug 03	-32	-252702.95	-39.5	52852	52883
Jul 03	-32	-252228.95	-39.5	52840	52852
Jul 03	-32	-251473.7	-39.75	52821	52840†
Jun 03	-32	-251076.2	-39.75	52811	52821
Jun 03	-32	-250276.2	-40.0	52791	52811†
May 03	-32	-249652.2	-39.0	52775	52791
May 03	-32	-249052.2	-40.0	52760	52775†
Apr 03	-32	-248495.7	-39.75	52746	52760
Apr 03	-32	-247855.7	-40.0	52730	52746†
Mar 03	-32	-247415.7	-40.0	52719	52730
Mar 03	-32	-246607.7	-40.4	52699	52719†
Feb 03	-32	-246284.9	-40.35	52691	52699
Feb 03	-32	-245474.9	-40.5	52671	52691†
Jan 03	-32	-244906.5	-40.6	52657	52671
Jan 03	-32	-244218.0	-40.5	52640	52657†
Dec 02	-32	-243813.0	-40.5	52630	52640
Dec 02	-32	-242964.6	-40.4	52609	52630†

† Rate change in mid-month

†† Rate change one day early

*Provisional value

7. SPECIAL ANNOUNCEMENTS

TRACEABLE FREQUENCY CALIBRATIONS (Now NVLAP Certified)

Laboratories can get any needed traceable frequency calibrations by subscribing to the NIST Frequency Measurement and Analysis Service. This service is offered on a lease basis by NIST to provide an easy and inexpensive means to obtain traceability of a laboratory frequency standard and, in addition, to calibrate other devices in the lab. This service has been designed for ease of operation and as a practical calibration tool.

All necessary hardware and software is provided by NIST. Users must provide their own oscillator(s) and an ordinary telephone line so that NIST can access the system by modem. A maximum total of five oscillators can be calibrated at the same time. Radio signals from GPS satellites are used and the measurement uncertainty is $\pm 2 \times 10^{-13}$ per day. Any frequency from 1 Hz to 120 MHz (in 1 Hz increments) can be measured.

The calibration data are displayed in color, and a graph is plotted daily for each oscillator. Data are also stored on disk. The user can call up any of the data and view them onscreen or in the form of plots. Up to 5 months of data can be plotted on one graph.

The system plots are easy to read and understand. The system manual is written clearly and the NIST staff are available by telephone to assist. The modem connection allows NIST to access the data and to prepare a monthly traceability report, which is mailed to the user.

Frequency sources of any accuracy can be calibrated. The FMAS is particularly useful at the highest levels of performance. This is because each user of the system contributes information and calibration data for the others. If an uncertainty arises, it is possible for NIST to call by modem to another user nearby. In this way problems in data interpretation can be resolved.

NVLAP certification requirements for frequency measurement are met by following the NIST-FMAS operating manual. This service does not eliminate the NVLAP audits but, when installed and operated per the NIST guidelines, audit requirements are easily met.

NIST retains title to the equipment and supplies. All necessary replacement parts are replaced by overnight shipment. Training for use of the system is available if requested by the user.

The NIST Frequency Measurement and Analysis Service provides a complete solution to nearly all frequency measurement and calibration problems. For a free information package, please phone Michael Lombardi at (303) 497-3212, or E-mail him at lombardi@boulder.nist.gov, or write to Michael Lombardi, NIST, Division 847, 325 Broadway, Boulder, CO 80305.

NOTICE TO DISCONTINUE INVOLVEMENT WITH GOES TIME CODE SERVICE

NIST has announced that it will discontinue its involvement with the time code broadcast from the GOES WEST and GOES EAST satellites operated by the National Oceanic and Atmosphere Administration (NOAA) on January 1, 2005. This decision has been jointly made by NIST and NOAA in response to the fact that nearly all users requiring time more accurate than 1 millisecond now use the Global Positioning System (GPS), and as a result, commercial sources for GOES timing receivers no longer exist.

NOAA is expected to continue to provide a GOES time code indefinitely after January 1, 2005, and existing receivers should be able to continue to receive and decode the time signal. However, the time code will no longer be controlled and checked by NIST, and the received time is expected to be less accurate when NIST discontinues its involvement. The GOES satellites currently broadcast continuously updated position information in addition to the time, so that GOES receivers can automatically correct for path delay changes caused by satellite motion. This allows the current system to have a time uncertainty of less than 100 microseconds. NOAA is expected to continuously broadcast a fixed position from the satellites, which could increase the time uncertainty to 1 millisecond or more.

The GOES time broadcasts began in 1974 and have served many applications and thousands of users. NIST will continue to control and monitor the time code through January 1, 2005 to allow users who require a high accuracy signal sufficient time to replace their existing receivers. If you have additional questions, please contact Michael Lombardi, 303-497-3212, or email lombardi@boulder.nist.gov.

IMPORTANT NOTICE!

The Time and Frequency Bulletin data are now online at

<http://tf.nist.gov>
